REMARKS

Applicants respectfully request reconsideration of the present application in view of the foregoing amendments and in view of the reasons that follow. Claims 1-20 have been rejected. Claims 11 and 20 have been amended to correct typographical errors included therein and/or to more clearly recite the subject matter claimed therein. The Applicants note that such amendments have not been made for a reason related to patentability of the claims, and that no new matter has been added. Accordingly, Claims 1-20 will be pending in the present application upon entry of this Amendment and Reply.

A detailed listing of all claims that are, or were, in the application, irrespective of whether the claim(s) remain under examination in the application, is presented, with an appropriate defined status identifier.

Claim Rejections – 35 U.S.C. § 103(a)

On page 2 of the Office Action, Claims 1-20 were rejected as being unpatentable over U.S. Patent No. 6,204,179 to McTeer, in combination with the comments of the Examiner. The Applicants respectfully traverse this rejection.

Claim 1 is in independent form and recites, among other elements, "annealing the copper material at a low temperature for a long period of time, the long period of time being greater than 8 hours; and subsequently annealing at a higher temperature than the low temperature and for a shorter period of time than the long period of time the copper material to distribute at least one alloy element" (emphasis added).

Claim 8 is in independent form and recites, among other elements, "providing a first anneal to form large grain sizes in the copper material, the large grain sizes being between approximately 2,500 and 10,000 angstroms; and providing a second anneal to distribute alloy elements uniformly in the copper material" (emphasis added).

Claim 16 is in independent form and recites, among other elements, "first annealing the copper layer to cause grain growth over a long period of time, the long period of time

being greater than 8 hours; and second annealing the copper layer to distribute the at least one alloy element in the copper layer" (emphasis added).

In contrast, McTeer relates to a "copper diffusion barrier, aluminum wetting layer and improved methods for filling openings in silicon substrates with copper" and discloses at column 17, lines 22-58 (with underlining added for emphasis):

> FIG. 1 shows a cross-section of an insulating layer 1 of a silicon substrate having an opening which is overlaid with a $Ti_xAl_yN_z$ barrier layer 2 and then filled with copper 3. . . . The $Ti_xAl_yN_z$ barrier layer 2 is deposited by target sputtering (PVD) TiAl in a nitrogen atmosphere. . . . Copper 3 is then deposited over the $Ti_xAl_yN_z$ barrier layer 2 by PVD sputter to fill the opening. . . . The copper layer is then annealed by subjecting the silicon substrate so formed to an elevated temperature in a vacuum for a period of time less than 5 minutes. Alternatively, the anneal may be carried out by flowing in gases, such as hydrogen. After annealing, the copper is then caused to reflow at a temperature greater than about 500°C by techniques well known to one of ordinary skill in the art.

The Examiner acknowledged at page 2 of the Office Action that McTeer does not disclose "an annealing period of greater than 8 hours, grain sizes of copper material between 2,500 and 10,000 angstroms, and annealing temperatures of 100°C, 250°C to 350°C." Nevertheless, the Examiner indicated that it "would have been obvious to one having ordinary skill in the art at the time the invention was made to determine a suitable period of time, a grain size, and annealing temperatures."

The Applicants respectfully request that the Examiner provide evidentiary support (e.g., documentary evidence) in support of the contention that such features would have been obvious. See M.P.E.P. § 2144.03 (noting that "official notice" of facts should be rare and used only in circumstances where such facts are "capable of instant and unquestionably demonstration as being well-known").

The annealing steps disclosed in the above excerpt from McTeer differ from those recited in independent Claims 1, 8, and 16. In fact, there is no teaching or suggestion in McTeer that would indicate that McTeer recognized the difficulty identified by the

Applicants, which is described, for example, at paragraphs [0009]-[0010] of the present application:

> **[0009]** Blocking electromigration in copper material by clogging grain boundaries with alloy elements is dependent on copper grain size and alloy element diffusion kinetics. Generally, the alloy elements should not be distributed within the grains of the copper structure. Instead, it is desirable to diffuse the alloy elements so that the copper grain boundaries are effectively clogged, thereby reducing electromigration problems. At higher temperatures, alloy elements can be diffused into the copper grains. Accordingly, the alloy elements must be distributed in the copper material sufficiently to clog grain boundaries without affecting the copper grain structures for optimized performance.
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> **[0010]** It is a challenge to control copper grain growth and alloy distribution when forming copper lines and other structures. It is particularly difficult to control alloy element distribution if the alloy is introduced prior to copper grain growth.

As noted at paragraph [0023] of the present Application,

> **[0023]** Applicants have observed the grain sizes in copper lines grow if allowed to anneal over a long period of time (e.g., 24 hours or longer) at low temperatures. Applicants have applied this concept to conductive line formation. Applicants believe that the grain size can be increased separately from an annealing step to clog grain boundaries of the conductive line with alloy elements. The two step annealing process improves the copper structure over conventional annealing processes.

Various exemplary embodiments are described at paragraphs [0048] and [0050] of the present Application (with underlining added for emphasis):

> **[0048]** In step 110, layer 34 is allowed to self-anneal over a relatively long period of time such as 24-48 hours at a temperature of less than 100°C (e.g., room temperature). In an alternative embodiment, a low temperature anneal at a temperature of approximately 60°C for between approximately 8-24 hours can be utilized. Due to the low temperature anneal, there is relatively little appreciable diffusion or motion of alloy

> elements from layer 28 or 32 when grain growth of material 34 occurs.
>
> **[0050]** In step 122, conductive line 52 (including layer 34) is further annealed with annealing conditions tailored exclusively for the needs of distributing alloy elements without affecting copper grain structure. In one embodiment, a furnace anneal of less than 400°C (e.g., 250-350°C) for a shorter period of time than the anneal in step 110 may be performed. The annealing parameters can be adjusted according to the type of alloy elements utilized and other factors. In one embodiment, if 1.0 atomic percent tin (Sn) is utilized as an annealing element, step 122 provides a 250°C temperature anneal for approximately 600 seconds.

There is no teaching or suggestion that McTeer recognized the need to provide separate anneals for allowing grain growth and for distributing alloy elements or that the anneals described therein would be suitable for accomplishing such goals. In contrast, McTeer indicates that a "copper layer is . . . annealed by subjecting the silicon substrate so formed to an elevated temperature in a vacuum for a period of time less than 5 minutes," after which "the copper is then caused to reflow at a temperature greater than about 500°C."

Accordingly, the steps of "annealing the copper material at a low temperature for a long period of time, the long period of time being greater than 8 hours; and subsequently annealing at a higher temperature than the low temperature and for a shorter period of time than the long period of time the copper material to distribute at least one alloy element" as recited in Claim 1 are not taught or suggested by McTeer.

The steps of "providing a first anneal to form large grain sizes in the copper material, the large grain sizes being between approximately 2,500 and 10,000 angstroms; and providing a second anneal to distribute alloy elements uniformly in the copper material" as recited in Claim 8 and the steps of "first annealing the copper layer to cause grain growth over a long period of time, the long period of time being greater than 8 hours; and second annealing the copper layer to distribute the at least one alloy element in the copper layer" as recited in Claim 16 are also not taught or suggested by McTeer.

Further, the Applicants submit that the subject matter recited in independent Claims 1, 8, and 16 involve more than "discovering the optimum or workable ranges" that "involves only routine skill in the art." The Applicants have recognized a problem that was not appreciated by McTeer and have developed a solution for that problem. There is no teaching or disclosure in McTeer that would support the contention that the subject matter recited in independent Claims 1, 8, and 16 would have been obvious to one of ordinary skill in the art reviewing the disclosure of McTeer.

The rejection of Claims 1-20 should be withdrawn, because at least one limitation of independent Claims 1, 8, and 16 is not taught or suggested by McTeer. Accordingly, the Applicants request reconsideration and withdrawal of the rejection of Claims 1-20 under 35 U.S.C. § 103(a).

It should also be noted that various claims are allowable for reasons in addition to those described above. For example, Claim 1 recites "providing a seed layer in the trench" and Claim 8 recites "providing a copper seed layer." McTeer does not teach or suggest the use of a "seed layer" or a "copper seed layer" as those terms are used in Claims 1 and 8. The Examiner stated at page 2 of the Office Action that "McTeer discloses . . . providing a copper seed layer 2 in the trench." However, as noted at column 17, line 24 of McTeer, the layer denoted with reference numeral "2" is actually a "$Ti_xAl_yN_z$ barrier layer 2." Accordingly, the Applicants submit that Claims 1 and 8 (and corresponding dependent Claims 2-7 and 9-15) are allowable over McTeer. Reconsideration and withdrawal of the rejection of Claims 1-15 is therefore respectfully requested.

Claim 14 recites "providing additional alloy elements in a layer above the copper material." The Applicants submit that McTeer does not teach or suggest providing such alloy elements in a layer above a copper layer. Reconsideration and withdrawal of the rejection of Claim 14 is therefore respectfully requested.

Claim 8 recites "providing a second anneal to distribute alloy elements uniformly in the copper material." Claim 11 recites "wherein the alloy elements include at least one of tin (Sn), calcium (Ca), chromium (Cr), zinc (Zn), zirconium (Zr), hafnium (Hf), and lanthanum

(La)." The Applicants submit that McTeer does not teach or suggest providing an anneal to distribute alloy elements, and further does not teach or suggest the use of alloy elements such as tin (Sn), calcium (Ca), chromium (Cr), zinc (Zn), zirconium (Zr), hafnium (Hf), and lanthanum (La). Accordingly, the Applicants respectfully request reconsideration and withdrawal of the rejection of Claims 8-15.

Claim 16 recites "providing a source of at least one alloy element" and Claim 20 recites "wherein the at least one alloy element includes at least one of zirconium (Zr), hafnium (Hf), and lanthanum (La)." The Applicants submit that McTeer does not teach or suggest providing a source of at least one alloy element, and further does not teach or suggest that such alloy element is one of zirconium (Zr), hafnium (Hf), and lanthanum (La). Accordingly, the Applicants respectfully request reconsideration and withdrawal of the rejection of Claims 16-20.

* * *

It is submitted that each outstanding objection and rejection to the Application has been overcome, and that the Application is in a condition for allowance. The Applicants request consideration and allowance of all pending Claims 1-20.

The Examiner is invited to contact the undersigned by telephone if it is felt that a telephone interview would advance the prosecution of the present application.

The Commissioner is hereby authorized to charge any additional fees which may be required regarding this application under 37 C.F.R. §§ 1.16-1.17, or credit any overpayment, to Deposit Account No. 06-1447. Should no proper payment be enclosed herewith, as by a check being in the wrong amount, unsigned, post-dated, otherwise improper or informal or even entirely missing, the Commissioner is authorized to charge the unpaid amount to Deposit Account No. 06-1447. If any extensions of time are needed for timely acceptance of papers submitted herewith, Applicants hereby petition for such extension under 37 C.F.R. §1.136 and authorizes payment of any such extensions fees to Deposit Account No. 06-1447.

Respectfully submitted,

Date 2/18/2005 By _____

FOLEY & LARDNER LLP
Customer Number: 26371
Telephone: (414) 297-5564
Facsimile: (414) 297-4900

Marcus W. Sprow
Attorney for Applicants
Registration No. 48,580